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भारतीय मानक

इस्पात के ऊष्मा उपचार की रीति संहिता

Indian Standard

**CODE OF PRACTICE FOR
HEAT TREATMENT OF STEEL**

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BUREAU OF INDIAN STANDARDS
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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Metallography and Heat Treatment Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard has been prepared with a view to guide the industry regarding various practices being followed for heat treatment of steel.

Indian Standard

CODE OF PRACTICE FOR HEAT TREATMENT OF STEEL

1 SCOPE

1.1 This standard describes the heat treating procedures, temperature schedules, equipment requirement and other details relating to the heat treatment of plain carbon and low alloy steels.

2 TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS 1956 shall apply.

3 TYPES OF HEAT TREATMENT

3.1 The various types of heat treatments generally applied to carbon and low alloy steels are as follows:

- a) Stress relieving,
- b) Normalising,
- c) Annealing,
- d) Hardening,
- e) Tempering,
- f) Special heat treatment,
- g) Case hardening, and
- h) Surface hardening.

3.1.1 Stress Relieving

Stress relieving is carried out to reduce internal stresses that remain within the product as a result of manufacturing processes so as to stabilize its properties and dimensions.

The process consists in heating the material slowly and uniformly to a suitable temperature below the transformation range (AC_1 for ferritic steels), holding at this temperature for a pre-determined time, followed by slow and uniform cooling to minimize the development of new internal stresses.

Stress relieving temperatures typically range between 180-300°C for low alloy ferritic steels, whereas temperatures for higher alloy varieties are higher. The relief of residual stresses is related to both temperature and time and similar relief can be achieved by prolonged holding at a lower temperature.

3.1.2 Normalising

Normalising of steel is carried out to refine grain size, ensure structural homogeneity, modify residual stresses, enhance machinability etc.

Normalising is accomplished by heating carbon steel to about 50°C above the upper critical line of the iron-iron carbide diagram that is; above AC_3 for hypoeutectoid steels and AC_1 for hyper-eutectoid steels, followed by cooling in still or agitated air.

Generally the heating rate in normalising is not critical. However special precaution should be taken to minimise distortions caused by thermal stresses in parts/components having large variations in section size. The holding time at the austenizing temperature should be sufficient to ensure homogenization and for dissolution of carbides, if present. As a general guideline, an hour per 25 mm of part thickness may be used to calculate the soaking period.

The cooling rate is of significant importance as it influences the amount of pearlite, its size and spacing of the pearlite lamellae. Higher cooling rate may be employed to increase the strength and hardness of the parts. After the steels are cooled down evenly to black heat below A_1 , they may be water or oil quenched to decrease the total cooling time.

3.1.3 Annealing

Annealing denotes the heating of steel above a suitable temperature holding for appropriate time, followed by cooling at a suitable rate. Steels may be annealed to achieve softness, produce desired microstructure, enhance ductility, relieve internal stresses, improve machinability, etc. Generally annealing is a preparatory heat treatment that is applied to castings, forgings and rolled stock, although in some cases, for instance heavy castings, it is used as a final treatment.

3.1.3.1 Full annealing

- i) Full annealing consists in heating steels 30 to 50 degrees above the critical point AC_3 in case of hypoeutectoid and between AC_1 and AC_m for hypereutectoid steels holding for suitable time and slowly cooling usually in a furnace. Unless otherwise specified annealing in case of carbon steels implies to full annealing.
- ii) Heating the steel too high a temperature above AC_3 shall be avoided to prevent austenite grain growth which is detrimental to mechanical properties.
- iii) The heating time and the holding time at the annealing temperature shall depend upon the type of furnace used, the

arrangement of workpieces inside the furnace, the height of the charge and the kind of materials being annealed.

- iv) The cooling rate from the annealing temperature shall be slow enough to allow austenite decomposition at lower degrees of super cooling to prevent the formation of ferrite-cementite dispersions of high hardness. The cooling rates for alloy steels should be lower than those of carbon steel.

The slow cooling may be accomplished by cooling the charge within the furnace and by having the heating facilities completely switched or gradually reduced.

3.1.3.2 Isothermal annealing

- i) Isothermal annealing is mostly applicable to alloy steels which necessitate very slow cooling, for reducing the overall time required for heat treatment as compared to conventional full annealing. In this process, the steel is heated as in ordinary annealing and then rapidly cooled to a temperature lower than A_1 . The steel is held isothermally at this temperature for sufficient time to complete austenite decomposition and is subsequently cooled rapidly in air.
- ii) From a practical standpoint, it is not suitable to carry out this heat treatment in a conventional batch furnace of large heat capacity owing to difficulties in rapid lowering of temperature. Usually two muffle furnaces or a continuous furnace with different temperature zones is made use of this heat treatment.

3.1.3.3 Spheroidizing

- i) Spheroidizing of steel is carried out to impart the softest condition and improve the machinability substantially through the development of a finely dispersed structure of globular carbides or granular instead of a lamellar pearlite obtainable from conventional full annealing.
- ii) The extremely good ductility of spheroidized microstructures is important for low and medium carbon steels that are to be cold formed. Also, the low hardness achieved through spheroidization improves the machinability of high carbon steels that undergo extensive machining.
- iii) Spheroidizing may be accomplished by any of the following methods:
 - Substantially long holding at a temperature below Ac_1 .
 - Alternate heating and cooling in the temperature range, that is, just above Ac_1 and just below Ar_1 .

— Heating slightly above the Ac_1 temperature, and then either cooling extremely slowly in the furnace or holding at a temperature just below Ar_1 .

Proper temperature control is necessary for the success of the spheroidizing process as overheating would cause the formation of lamellar pearlite instead of granular/blobular pearlite. The cooling rate should be very slow to enable austenite decomposition into the ferrite-carbide aggregate and coalescence of carbides.

3.1.3.4 Homogenization (diffusion annealing)

- i) Homogenization annealing is applied to alloy steel ingots and large castings to reduce dendritic and inter-crystalline segregation which result in loss of ductility and toughness of alloy steels.
- ii) Steel for this treatment is heated to a high temperature (1100° to 1200°C) to ensure the completion of diffusion processes necessary for composition equalisation. The holding time for homogenization is dependent upon the steel composition and the mass of the charge and is kept minimal for minimising oxidation and scaling that occur at such high temperature.
- iii) Homogenization results in a coarse grain size which is eliminated during subsequent working of the ingot. However in case of foundry castings, annealing or normalizing is subsequently resorted to refine the grain and improve properties.

3.1.3.5 Process annealing

- i) Process annealing is an in-process subcritical annealing treatment, usually applied to cold worked steel products to restore ductility and make them amenable for subsequent working.
- ii) The treatment involves heating steel to a temperature slightly below A_1 , soaking for an appropriate time, followed by cooling in air. Process annealing temperatures well below Ac_1 are generally used for softening a material prior to cold sawing and cold shearing.
- iii) The treatment is also extensively used in the wire industry for producing 'annealed in-process' wire or for the production of soft wire suitable for severe upsetting and to permit the drawing of low carbon and medium carbon steel wire rods to smaller sizes.

3.1.4 Hardening

3.1.4.1 Hardening of steel involves heating to a temperature from 30 - 50°C above Ac_3 (for hypoeutectoid steels) and above point Ac_1 (for hypereutectoid steels) holding until the completion of phase transformation, followed by cooling at a rate greater than the critical cooling rate.

3.1.4.2 Heating rate

The heating rate up to the austenizing temperature depends upon the steel chemistry, initial microstructure, shape and size of the work and the type of heating facility used. The rate should be less for steels with higher carbon and alloy content as well as for large components of intricate shapes.

3.1.4.3 Heating temperature and time

When the specified heating temperature is reached, the work should be held at this temperature for sufficient time to ensure temperature equalization throughout the section and completion of necessary phase transformation. In general, plain carbon and low alloy steels containing easily dissolvable carbides may require very small holding time.

Higher heating temperatures should be avoided as it results in coarse grained structure and larger percentage of retained austenite upon quenching. In addition, it may also result in surface oxidation and decarburization. Steel for hardening shall be protective against oxidation and decarburization by heating to protective gaseous media, molten salts or vacuum.

3.1.4.4 Quenching

Quenching involves rapid cooling of the steel from the austenizing temperature by immersion in water, oil, molten salts, brine or polymer solution to develop a suitable as quenched microstructure.

Selection of proper quenching media shall be done in accordance with the specific steel chemistry, section size, etc, so that distortion, warpage and quench cracking in workpieces are avoided. The effectiveness of the quenching may be improved by suitable agitation.

3.1.5 Tempering

3.1.5.1 Tempering consists in heating previously hardened steel to a temperature below the transformation range (A_{c1}), holding and subsequent cooling at a specified rate with the objective of increasing ductility and toughness. Tempering also helps in relieving quenching stresses and ensures dimensional stability.

3.1.5.2 Tempering is performed in either a muffle furnace, salt, molten metal or oil baths etc. Steel components that have been heated or quenched in salts baths must be freed from any adhering salt before tempering in muffle or convection furnace by rinsing in warm water. The process shall be accomplished by soaking entire parts/components at a specific temperature for a time period sufficient to ensure completion of the tempering mechanism or by selective heating of certain areas of the part to achieve localized toughness or plasticity.

3.1.5.3 The principal variables in temperature, namely, tempering, time of holding and the

cooling rate shall be properly adjusted to achieve the desired mechanical properties.

3.1.6 Special Heat Treatment

3.1.6.1 Martempering

Martempering or more appropriately termed 'marquenching' is an elevated temperature quenching procedure aimed at reducing cracking, distortion and residual stresses in steels. Martempering involves, quenching steel from the austenitizing temperature, into a hot liquid maintained or just below the M_s temperature holding in the quenching medium to ensure temperature equalisation throughout the workpiece, followed by air cooling to room temperature. Martempered parts however exhibit brittleness owing to the essentially martensitic microstructure and hence necessitate tempering for restoring toughness. Martempering is generally applicable to alloy steels, but some carbon steels that are conventionally water quenched can be martempered in sections not thicker than 5 mm using vigorous agitation in the martempering bath. Low-alloy steels that are suitable for martempering can be martempered in thicker sections up to 19 mm.

3.1.6.2 Austempering

Austempering of steel consists in isothermal transformation of the austenite at a temperature lower than that of pearlite formation and above that of martensite formation, resulting in the formation of a bainitic microstructure. Austempering is usually substituted for conventional quenching and tempering to obtain increased ductility and notch toughness at a given hardness and to also reduce cracking and distortion. The steels that are suitable for austempering are :

- i) Plain carbon steels 0.5 to 1.00% C and not less than 0.6% Mn.
- ii) High carbon steels, having more than 0.9% C and Mn slightly lower than 0.60%.
- iii) Carbon steels containing less than 0.50% C, but higher Mn in the range of 1.00 to 1.65%.
- iv) Certain low alloy steels.

3.1.6.3 Patenting

Patenting is a heat treatment process that is applied to high carbon steel wire rods and 'in process' wires to develop a fine sorbitic structure that is amenable to large area reductions in cold drawing to high strength levels.

The heat treatment can be performed in a 'continuous' or 'batch manner by austenizing steel 30°-50°C above A_{c3} , soaking for appropriate time, followed by isothermal quenching in lead or molten salt baths maintained in between 450°-550°C depending upon the steel composition.

3.1.7 Case Hardening

3.1.7.1 Carburizing

Carburizing of steel consists of increasing the surface carbon content so that upon heat treatment, a hard layer of martensite is produced. This is mainly applicable for low carbon steel having low hardenability, thus facilitating the production of a hard external surface with a tough core. Depending upon the physical state of the carburizing media, the process is known as pack carburizing, liquid carburizing and gas carburizing. Steel grades suitable for carburizing are covered by IS 4432 : 1967, which also gives the details of carburizing, hardening and tempering treatment of these steels.

3.1.7.2 Carbonitriding

- i) Carbonitriding is carried out by addition of ammonia to the gas carburizing atmosphere so as to simultaneously saturate the surface of steel with both carbon and nitrogen. The treatment is generally carried out by heating the steel at 850°-870°C and holding for 2 to 10 h depending upon the depth of case desired. Carbonitriding is followed by quenching directly from the furnace or after reheating. These hardened parts are tempered at 160° to 189°C so as to obtain case hardness of 60-62 Rc.
- ii) Carbonitriding is generally applied to components of complex shapes, for example gears which are prone to warping. However compared to carburizing, this treatment has limited usage because case depths attainable are restricted to a maximum of 1 mm.
- iii) The main advantages of carbonitriding over gas carburizing are :
 - Lower heat treatment temperature.
 - Higher hardenability of the case, enabling oil quenching with lesser tendency of warpage and cracking.
 - Higher wear and corrosion resistance of case.

3.1.7.3 Nitriding

- i) Nitriding consists in saturating the surface of steel with nitrogen by heating it in an ammonia atmosphere at a temperature of 500°-600°C. Nitriding increases the hardness, wear resistance, endurance limit, corrosion resistance of the surface layer by creating a thin case containing alloy nitrides. The nitriding treatment can also be carried out by heating steel parts in molten cyanide cyanate baths containing salts of sodium and potassium. Now-a-days plasma nitriding equipments are available and can also be utilized for this treatment.

- ii) Nitriding is generally applied to medium carbon low alloy steels containing chromium, molybdenum and aluminium. Aluminium containing steels produce a nitrided case of very high hardness, excellent wear resistance, but of low ductility. The depth of the nitrided case depends upon the temperature and time of treatment. Use of higher nitriding temperature is to be avoided as this leads to thicker case with lower hardness. Nitriding is normally applied as a final heat treatment and best results are obtained on the steel which has been quenched and tempered before this treatment. Nitriding is extensively applied in the manufacture of components, such as gears, engine cylinders, machine tools etc.

3.1.7.4 Cyaniding

- i) Cyaniding is performed by heating steel in a bath of molten alkali cyanides, mixed with chlorides and carbonates to saturate the surface with carbon and nitrogen simultaneously. Generally the salt bath contains about 30% NaCN, 40% Na₂CO₃ and 30% NaCl. However for specific applications, higher cyanide content may be employed to achieve desired results. This treatment is followed by hardening and tempering to achieve a case hardness of 60 ± 2 Rc.
- ii) The case depth may be controlled by suitable selection of bath temperature, composition and holding time. As a guideline, treatment temperature in the range of 820°-860°C produces a thin case (0.15 to 0.35 mm) in 30 to 90 minutes holding time. For greater case depth (0.5 to 2.0 mm), cyaniding is to be performed at 930°-960°C for longer holding times varying from 1.5 to 6 h.

3.1.8 Surface Hardening

3.1.8.1 Induction hardening

- i) In induction hardening, localized heating of the surface to its austenitizing temperature is accomplished by eddy current induced by an alternating magnetic field which surrounds the steel. The depth of hardened layer decreases with increasing current frequency. Generally induction hardening is carried out at frequencies of 1000 Hz or more. In addition to frequency, the depth of penetration of the current increases with temperature, particularly pronounced at temperatures above the Curie point (768°C), accompanied by a reduction in the heating rate. Following austenitization, parts are quenched in water, oil or

air depending upon the grade of steel and then subjected to low temperature tempering at 160-200°C.

ii) Induction hardening is generally applicable to steels having carbon content in the range of 0.30-0.50% where surface hardness values in the range of 50-60 Rc can be obtained. Induction hardening shall be applied to steels which have been hardened and tempered or normalised. Fully annealed steels are not preferred for this treatment because the shorter heating-up times in induction hardening are not sufficient for carbide dissolution, thereby resulting in lower and inconsistent hardness values.

iii) This treatment is generally used for crank shafts, cam shafts, gears, automobile components, etc.

3.1.8.2 Flame hardening

i) This treatment is similar to induction hardening but employs high temperature flame to austenitize the surface of steel. The temperature flame is obtained by combustion of a mixture of fuel gas such as acetylene or propane with oxygen or air. Flame heads are used for burning the mixture and are of slit-type (having a single orifice in the form of a slit) or of multiple orifice type.

ii) In flame hardening, there is a risk of oxidation and overheating of the steel. Strict control on heating time, fuel and oxygen consumption is necessary. With this type of surface hardening, a hardened layer of 2-4 mm thickness with 50-55 Rc hardness can be obtained. This technique is generally used for large work such as mill rolls, heavy shafts, large gears and dies, machine ways etc.

3.1.8.3 'Laser Surface Hardening' and 'Electron-Beam Heat Treating' can also be employed for austenitizing the steel for surface hardening.

4 HEAT TREATING EQUIPMENT

4.1 Heating Media

Air, fluidized bed, molten salt baths, vacuum and protective atmosphere furnaces are suitable for heat treatment of steels. Proper selection of heating media and necessary tools and fixtures should be done so as to avoid damage to the parts being heat treated.

4.1.1 Air-Chamber Furnaces

Air-chamber furnaces in which electrical resistance heating is employed may be used for heat treatment of those products which have demonstrated by test to be substantially free from high temperature oxidation after heat treatment in

the furnace in question. Larger furnaces need be fitted with air circulation system so as to ensure temperature uniformity and prevent localized overheating. The use of such furnaces may be restricted to low temperature heat treatments, such as tempering, stress-relief annealing etc, as well as conventional annealing and normalizing.

4.1.2 Salt Baths

Salt bath furnaces can be used for a variety of heat treatments, such as normalizing, hardening, tempering, austempering, martempering, chemical heat treatments etc. Salt bath furnaces facilitate rapid heating rates and better thermal control. These furnaces may be externally heated by gas or oil or by means of electrical resistance or internally heated by immersed or submerged electrodes. Salt baths shall be maintained in good condition by regular regeneration since during usage, the iron build up in the bath gets oxidized and has a tendency to cause decarburization of the steel charge. The bath may be checked time-to-time for iron build up, carburizing or decarburizing character as advised by the salt manufacturer. The salts used in the salt baths shall be of a type and grade which will not react with the steel charge. The steel charge should be free from moisture, oil and dirt before heating in the bath. The salt on the heat treated stock should be removed soon after removal from the bath as the salts, being mostly hygroscopic are liable to cause corrosion. Heating in salt baths should be avoided for parts with small holes/openings, intricate joints from which it is difficult to completely remove salts.

4.1.3 Protective Atmospheres

Atmosphere control may be employed to avoid deterioration of the surfaces of steel stock subjected to elevated temperature and particularly when the heat treatment is a final operation. In addition, controlled atmospheres are also employed to provide the source of elements in some heat treating processes or bring about surface cleaning of parts being treated. Commonly used atmospheres for heat treating are gaseous mixtures containing carbon monoxide, carbon dioxide, methane, nitrogen, hydrogen and argon. The proper selection of the type of atmosphere and the specific amounts of the gaseous components depend upon the characteristics of the charge and the degree of surface protection desired.

4.1.4 Vacuum Furnaces

Heat treatment in vacuum furnaces consists in foreword processing of stock in enclosures that are evacuated to partial pressure levels below torr. 10^{-2} . During heat treatment, vacuum is used throughout or for a part of the entire cycle. Generally after the charge has been heated and austenitized under vacuum, cooling is carried out to room temperature using

nitrogen or argon atmosphere. Vacuum furnaces are increasingly employed for annealing, hardening and tempering, stress relieving, austempering etc. Although vacuum furnaces are normally of the batch-type, continuous furnaces with multiple zones may also be used.

4.1.5 Temperature Uniformity

The design and construction of batch furnaces and baths shall be such that during the heating up and soaking period, the air and metal temperature at any point in the working or austenitizing zone shall not exceed 10°C of the heating temperature for the specific steel being heat treated. After the stock reaches the temperature the design of furnaces or baths with their temperature controlling equipment shall be such that the temperature of the heating media and metal at all points in the soaking zone are maintained within maximum of $\pm 5^{\circ}\text{C}$ of the furnace control set temperature. For continuous furnaces the soaking zone is that part of the working zone in which the metal temperature is within the required austenitizing range. The design and construction of continuous furnaces shall be such that during the heating-up and soaking period, the metal temperature at any point in the working and soaking zone shall not exceed more than 10°C .

4.2 Pyrometric Equipment

A sufficient number of suitable temperature control devices, properly arranged should be provided on all heat treating equipment to assure adequate control of temperature in all working and soaking zones. The devices shall be so located as to avoid exposure to excessive dust, vibration and temperature outside the range of $0-100^{\circ}\text{C}$.

4.2.1 Temperature Measuring and Recording Equipment

Automatic controlling and recording instruments shall be used. Instruments shall be of the potentiometer type. Temperature sensing elements should be located in, or as close as possible to the working zone. The exact location of temperature sensing elements shall be in such a place as to give accurate measurement of the working or austenitizing or both zone temperatures.

4.2.2 Accuracy

Temperature readings should be adjusted to within $\pm 5^{\circ}\text{C}$ of true temperature by applying corrections established by calibrating equipment. If correction greater than $\pm 5^{\circ}\text{C}$ are indicated the source of error should be determined and adjustments to the measuring equipment shall be made so that the reading represent a true temperature within $\pm 5^{\circ}\text{C}$ or less.

4.2.3 Temperature of every furnace should be checked atleast once a month, both at the bottom of the furnace and along the height.

After replacing heating elements or after major repairs such a relining, the furnace must undergo a compulsory scheduled inspection. On the basis of this inspection data, working area where stock shall be placed for heat treatment is to be established.

4.2.4 In case of salt baths, periodic checking of the bath temperature and working of the temperature regulator shall be carried out atleast once during a shift by an inspection thermocouple. The results of such inspection should be systematically documented for facilitating calibration and remedial action.

4.3 Quenching Equipment

Suitable equipment for water, polymer solution or oil as well as gas quenching shall be provided. Care to be taken to maintain water quenching tank temperature in the range of $20-40^{\circ}\text{C}$. Shop should have sufficient ventilation and facilities for protection against hazards.

4.3.1 Quenching Baths

Means shall be provided for circulation of the quenching media and for heating or cooling, as necessary. Tanks shall be of adequate size for the workload involved in order to ensure that satisfactory quenching rates are attainable.

4.3.1.1 All water-baths employed in quenching parts which have been heated in salt-bath furnaces shall be provided with a drain and inflow of fresh water to prevent a concentration of dissolved salts in the tanks.

4.3.1.2 Conventional and fast quenching oils can be employed to achieve specific properties. The gravity, flash point, fire points, viscosity etc, for oil quenching media should be checked.

4.3.2 Location of Quenching Equipment

Quenching equipment should be located in such manner and handling facilities should be so arranged and equipped, as to permit rapid transfer of the load from the heating medium to the quenching medium.

4.4 Rinsing Equipment

Rinse tanks or sprays or any other suitable processing should be employed for removing salt residues or film from the surfaces of materials which have been immersed in molten salt baths or quenched in polymer solution. Separate rinse tanks or sprays may not be necessary if it has been demonstrated that the quench bath, under maximum load condition, is capable of removing salt residues without becoming so contaminated that its efficiency is impaired.

5 RECOMMENDED PROCEDURE AND OPERATIONS

5.1 Heat Treating Operations

Heat-treating operations shall be performed on the whole of a part or piece of material, never

on a portion only and shall be applied in a manner that will produce the utmost uniformity.

5.2 Charging of Furnaces and Baths

Material being heat treated shall be supported in such manner as to permit free access of the heating or quenching media in order to facilitate heating and cooling the material to a uniform temperature in a minimum time interval. Furnaces shall not be charged during unstable temperature conditions following upward or downward furnace setting. The time required for attaining stability following such change depends upon furnace construction and condition, as well as the degree of change of furnace setting during heat treating operations.

5.3 Cleaning of Materials

Surface of material should be substantially free from oils, grease, dust and other foreign matter which could harm material being heat-treated. All parts particularly when they are heat treated in the molten salt baths should be dried since moisture reacts with the hot salts violently.

6 INSPECTION AND TESTING OF HEAT-TREATED MATERIAL

6.1 Inspection and testing of the finished heat treated stock constitutes the most important aspect of quality control. This aims at establishing whether the processed material conforms to applicable specifications and standards.

6.2 Inspection for small sized parts shall be carried out on the basis of 'Complete Screening' or by 'Sampling inspection' as agreed upon by the manufacturer and the customer. Large components shall be subjected to piece-by-piece inspection. A number of similar articles manufactured from the same steel and subjected simultaneously to the same heat treatment shall be considered as a 'batch'. The number of parts for 'Sampling inspection' shall depend upon the size of individual parts, quantity of batch heat treated and the importance of the components under consideration. As a general guideline, 5-10% of the components shall be evaluated.

6.2.1 Visual Inspection

Visual inspection of the heat treated articles is conducted to see whether the articles are free

from surface defects, such as, cracks, distortion, warpage, scale etc. Extremely fine defects (internal cracks) that are hardly visible may be checked by special crack-detecting methods as agreed upon between the manufacturer and the customer.

6.2.2 Mechanical Testing

Heat treated parts may be subjected to various mechanical tests, such as hardness, tensile strength, yield strength, percentage elongation, reduction in area and impact strength. Hardness measurements are to be routinely performed to as a heat treatment process check. Parts and configurations which do not permit measurement of hardness must be, during heat treatment, accompanied by test specimens from the same stock. The number of such test specimens should be atleast two. In case higher hardness values are observed in quench and tempered parts, the manufacturer may resort to further tempering treatment to achieve desired properties. Evaluation of other mechanical properties, such as tensile strength, yield strength, percentage elongation, impact strength shall be carried out in accordance with relevant IS specifications.

6.2.3 Microscopic Examination

Microscopic examination may be carried out from time-to-time by the heat treater as a valuable tool to monitor the quality of incoming steel stock, for in-process quality control and for customer inspection. Inspection of incoming steel stock is necessary prior to machining and subsequent heat treatment for detecting excessive decarburization or segregation, surface defects such as cracks and qualifying an alloy's hardenability according to grain size. The quality of pilot and production batches can be corroborated on the basis of actual microstructures attained. The metallographic investigations may be documented for internal records or as proof to customers that the required microstructure or case depth has been achieved.

6.2.4 Test Report

If desired by the customer, the heat treater shall supply a test certificate incorporating the results of all tests carried out on the heat treated material.

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Western : Manakalaya, E9 MIDC, Marol, Andheri (East)
BOMBAY 400093

{ 632 92 95, 632 78 58,
{ 632 78 91, 632 78 92

Branches : AHMADABAD, BANGALORE, BHOPAL, BHUBANESHWAR, COIMBATORE,
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